MSNE 415 – Ceramics and Glasses – Fall 2016 PJL 9Nov2016

Fundamentals of ceramic and glassy materials, including phase relations, theoretical properties, structure, bonding, and design. Required for BS in MSNE.

- **Instructor:** Peter Loos **on campus:** MEB 215 ploos@rice.edu
- **Office hours:** after class, by request, and others to be determined
- **Class Meets:** Tu+Th, 1:00-2:15pm in Keck 105
- **Prerequisites:** MSNE 301
- **Credits:** 3 semester-hours, standard letter grade
- **Textbook:** Ceramic Materials: Science and Engineering 2nd Ed. by Carter & Norton, Springer (2013) ISBN 10: 1461435226 / ISBN 13: 9781461435228 available from www.abebooks.com, www.bn.com, www.springer.com/materials/special+types/book/978-1-4614-3522-8 , etc. Available in downloadable e-book or hard-cover. Fondren has a copy of 1st edition but Instructor has not compared that with our textbook. 2nd Ed. has many nice qualities, but also quite a few errors. Keep a copy of the errata sheet (provided by Instructor) with the book and use them together.
- **Optional Reading:** Introduction to Ceramics, 2nd Ed. by Kingery, Bowen, & Uhlmann, (1976), Wiley. The international edition from www.abebooks.com is surprisingly inexpensive.
- **Grading:** Homework 45%, tests 40%, quizzes 15%. There will be about eight homework assignments, two tests, and two quizzes. Points may be deducted for assignments turned in late. Tests will be take-home, open book, open notes. Quizzes will be in class, limited time, closed book, closed notes.
- **Honor Code Policy:** **For every assignment** students must do all the writing, calculating, and analyzing themselves, must **not** examine or copy from any work done by any other student (past or present), and must include and sign the Rice Honor Pledge on work turned in. Plagiarism and other academic fraud will be addressed per the Honor System Handbook. **On homework assignments,** students are encouraged to talk to each other, the Instructor, or anyone else with knowledge of the subject. But for tests and quizzes no discussion is allowed except with Instructor.
- **References:** When quoting or giving data from a source other than the textbook, class lecture slides, or one's own original work, a proper reference must be given. Use ACS format per pubs.acs.org/doi/pdf/10.1021/bk-2006-STYG.ch014 or in simpler form at: http://library.williams.edu/citing/styles/acs.php
- **Software:** Students will use spreadsheets such as MS Excel or OpenOffice Calc for some of the homework and test calculations. For compatibility, all files should be saved in either XLS, DOC, or PDF format.
- **Absence Policy:** Students are expected to attend class. Lecture slides posted online are not a substitute for attending class and will not include everything of importance said in class.
- **Disability Support:** Any student with a disability requiring accommodation in this course is encouraged to contact Instructor after class or by phone and also Disability Support Services in Allen Center.

Goals for this course: Students will become knowledgeable about the structure, processing, properties, and performance of various ceramic and glassy materials. Also, this course addresses ABET General Criterion 3. Student Outcomes as follows:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data.
(e) an ability to identify, formulate, and solve engineering problems

as well as:

(1) Students will be familiar with the bonding and structures found in most ceramics and glass; the types of defects which arise in those structures; Kroger Vink notation for point defect reactions;

the creation, growth and annihilation of various defect types; and the material properties which result from such structures and defects.

(2) Students will acquire broad knowledge of the types of properties which can be achieved using ceramics and glass, and common uses for these materials, so that students will be able to solve new engineering challenges in which the material itself is a key aspect.

(3) Students will be able to use equilibrium phase diagrams to process ceramics and glass, and to manipulate their properties.

(4) Students will be able to assess the technical literature regarding ceramics and glass and understand diverse associated technologies, old and new.

Ceramics Resources On the Web

- American Ceramics Society: ceramics.org lots of publications, jobs, and educational resources, including CeramicTechToday http://ceramics.org/ceramic-tech-today
- NIST Structural Ceramics Database: www.ceramics.nist.gov/srd/scd/scdquery.htm and a paper about it: https://archive.org/details/jresv94n1p37
- Functional ceramic materials database www.ncbi.nlm.nih.gov/pubmed/18232678
- Minerals databases: webmineral.com , minerals.net , mindat.org
- Ceramic Industry magazine: www.ceramicindustry.com
- Textbook co-author Grant Norton's web page: www.mme.wsu.edu/~norton/ quality of the links range from useful and good to useless and dead. Use the Wayback Machine.
- List of 14 ceramics organizations: http://digitalfire.com/services/database.php?list=organizations
- Ceramic Abstracts: http://search.proquest.com/ which a proprietary database. If one accesses it from inside the Rice domain it should work OK, but otherwise not.
- Piezoelectric materials & articles: www.morgantechnicalceramics.com/products/product-groups/piezo-ceramic-components

Other Technical Resources:

- Compendex/Inspec All fields of Engineering, physics, electronics, etc. See MIT video (3:32).
- **SciFinder** The most comprehensive chemical information database, including articles, patents, conference papers, and theses. View Tutorials. Contact administrator for access.
- Web of Science/ Web of Knowledge High impact journal articles in all fields.
- Scopus Competitor to Web of Science. Includes all subjects and cited reference searching.
- CRC Handbook of Chemistry & Physics Searchable data on thousands of materials' structure and properties
- **American Society for Testing and Materials:** Annual Book of ASTM Standards In print, not online at Fondren. Instructor has several old volumes.
- DoD & Federal Standards & Specifications from the Defense Logistics Agency. See especially Quick search
- SAE Standards including Aerospace Materials Standards. Thousands for sale.
- **MRS Online Proceedings Library** Papers from the Materials Research Society (MRS) Symposium. 1980-present.
- The Hyperphysics web page at GeorgiaStateUniversity including condensed matter and its properties hyperphysics.phy-astr.gsu.edu/hbase/solcon.html#solcon
- Crystal lattice structures from the Naval Research Lab: cst-www.nrl.navy.mil/lattice/ also many useful links at: cst-www.nrl.navy.mil/lattice/others.html These pages were taken down a few years ago, so use the Wayback Machine https://archive.org/web/ .

Lecture Topics by week - All about Processing, Structure, Properties, and Performance

1) Introduction, examples of ceramics from nature and familiar devices "close to home".
2) Review of diodes, ceramic films and processes for integrated circuits, composites. Diverse properties and applications for ceramics, traditional vs. advanced ceramics.

3) Structure and processing methods for perovskite ferroelectric memory.
Hall-Petch relationship, safety, a brief history of ceramics.
Chemical bonding: ionic, covalent, metallic, van der Waals, & hydrogen emphasizing the Madelung constant and hybrid orbitals.
Ionic radii and the corresponding Hume Rothery solubility rule.
Crystal systems, Bravais lattices, Miller indices, close packed structures.
4) Lattice with a basis, planes of a zone, point group symmetry, screw axes, strukturbericht notation.
Substitutional and interstitial sites, packing of hard spheres, twins.
Pauling's Rules for ionic crystals, importance of crystal structure, binary compounds with simple structures.
5) GaN processing, properties, applications and Nobel prize.
More binary compounds and their structures, polymorphs, polytypes.
Ternary compounds including spinel & magnetite, perovskite processing.
Silicates, orthosilicates, garnets, mica, clay, aluminates, mullite.
6) Garnet simplified, silicon nitride & SiAlON, fullerenes, zeolites.
Glass structure, glass formation, and applications on integrated circuits.
Binary equilibrium phase diagrams, triple points, Gibbs phase rule, lever rule.
Experimental determination of phase diagrams.
7) Use of phase diagrams, ternary diagrams, cooling paths on the liquidus.
Oxygen gas pressure as a degree of freedom, quaternary diagrams,
Congruent and incongruent melting using BaTiO3 as an example.
8) Phase diagrams for glass, miscibility gaps.
Furnaces.
Materials characterization methods from common to exotic, ceramic sample preparation.
Point Defects, Kroger Vink notation
9) Color centers, concentrations and generation of point defects, their enthalpies of formation.
Solid solutions and Hume Rothery rules for solubility.
Diffusion of defects, ionic conduction.
Dislocations, their formation, stress and strain fields, interactions, point defect atmospheres.
Pons & Fleischmann, cold fusion at dislocation cores and recent LENR in layered structures?
Dislocation dissociation and stacking faults, and microscope observation.
Dislocations in specific ceramics, their generation, kinks and jogs.
10) More about ternary phase diagrams: lever rule, congruent vs. incongruent melting.
Identification of eutectic vs. peritectic points, Alkemade line and theorem.
Mechanical properties, importance of residual stress, test methods: bending and indentation, porosity,
Weibull statistics, effect of specimen volume on strength.
11) Plasticity, slip systems, Peierls-Nabarro Stress, effect of temp., strain rate, & solutes, Hall Petch effect,
Creep, creep mechanisms, viscous flow, deformation maps.
12) Brittle fracture, crack tip plasticity, stress/corrosion cracking, fatigue.
Fractography, toughening mechanisms, wear applications.
Raw materials, beneficiation, methods of synthesis, production and applications of SiC.
Milling, particle size separation and analysis methods.
13) Sol-gel synthesis of powders, fibers and foam.
Various other methods of producing powders, fibers, and whiskers. Fiberglass.
Fiber reinforced composites, their processing and optimization. Ceramic matrix composites.
Glass, its viscosity and other properties,
14) Viscosity measurement, crystallization velocity, electrical properties of glass.
15) Miscibility gaps, adding color, tendency to crystallize, use on IC chips, etching/corrosion.
Various types of glass, glass formation in nature. Fragile glass structures.